ILLUSTRATING THE TECHNICAL PRESENTATION

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ALTHOUGH most scientific reports are not primarily planned to produce attractive pages in a publication, some well illustrated reports approach this result.

Usually this effectiveness does not occur by chance, but is produced by carefully prepared, adequate illustrations. This paper is intended to assist authors who wish to improve their reports by learning to plan and produce better technical illustrations.

The achievement of a coordinated, illustrated report requires more than haphazardly tracing curves from the experimenter's notebook. Each chart or illustration that is to serve as an interesting focus in the text, as well as an aid to understanding, must receive ample consideration. To be most useful, the illustration must show data in ways that give the reader an instant comprehension of the subject.

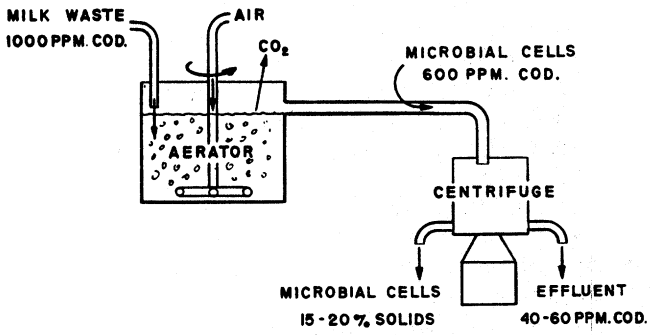

Figure 1. Good Diagram of a Process

Since illustrations are usually conceived when the author is concentrating on writing his manuscript, they may easily fail to receive proper attention. Therefore it is suggested that as the first step toward good charts and graphs the author give more thought to their selection, content, and form.

SELECTION

How can the data be illustrated to best advantage? The answer to this question depends entirely on the subject of the report. The author should examine his data carefully and make a preliminary selection of items for possible illustration. He should then review this list to eliminate repetition but still be sure the subject is covered. An attempt should be made to provide the most interesting illustration for the most important part of the topic. Since each illustration is placed close to its reference in the text, the sequence of the illustrations will follow the progress of the work being reported. In some cases, the effort to provide good continuity in the illustrations may suggest changes in the arrangement of the text. If a change will produce a clearer exposition or greater emphasis, it should be made. Illustrations and text should combine to give a clear, unified statement.

FORM AND CONTENT

Careful consideration should be given to the form and content of each drawing. To select the best form, the author needs to be familiar with the different types of drawings and their proper usage. The type of illustration most frequently used is the graph with a continuous curve showing the relationship of variables. This type of illustration is easily understood by the reader and when properly prepared is generally pictorially satisfying.

The continuous curve should not be used to illustrate periodic data. It gives the reader an erroneous idea of continuity of relationship that does not exist. The proper form of illustration for showing static values is the bar graph. Bar graphs may show more than one set of values, each series being identified by its particular cross-hatching. The bars may also consist of rows of symbols, such as silhouette drawings or dollar marks, which identify them.

It is suggested that some form of "pie" chart be used when the data show the relative parts of a whole. This easily constructed diagram does not appear as frequently as it might. Because the eye is able to compare both the area and central angle of one sector with any of the others in the chart, the reader easily grasps and retains the relative proportion of the parts demonstrated this way.

Drawings of apparatus and equipment also require considerable thought. There is a distinct difference between working drawings and illustrations. Working drawings should never be published with reports, since the many details required for correct manufacture of the equipment are not needed by the reader. The drawing that illustrates equipment or apparatus for a report must be made as simple as possible; all details except those to which the text refers should be eliminated. Illustrations of technical apparatus should be clear, well proportioned, and labeled with the names

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or functions of the parts. There should be no crowded or confusing areas on the drawing.

Figure 1 illustrates a good diagram of a process; it is simple, direct, and easy to understand. Figure 2 gives an example of the confusion caused by including too many details.

In attempting to work out the details of any illustration, it should always be borne in mind that there is a limit to the material that may be included in one drawing. This limit may be understood if the author assumes that some of his readers or audience are unfamiliar with the data. This unfamiliarity requires that complicated ideas should be explained in small, easily understood steps. If the author fails to recognize and stay within the bounds of assimilable illustrations, his readers or listeners will miss important points and lose interest. Crowded drawings may easily confuse the subject rather than clarify it. Furthermore, the author will find that limiting the quantity of data will simplify making the drawing.

LANTERN SLIDES

When a lantern slide is to be made, it is recommended that the drawing be made to fit the size and shape of a slide opening. Fortunately, prepared commercial slide masks are made with openings of many shapes and sizes, so that this is not difficult. It should be pointed out, however, that only the large openings having a greater width than height use the screen space efficiently when projected. The table gives dimensions of the openings in some of the more frequently used slide sizes.

Instead of allowing the photographer who makes the slide to choose the mask opening to fit the drawing, it would be better for the author to plan the drawing proportion to fit a definite slide opening. The most satisfactory arrangement is for the author to select a slide opening and make the drawing three to four times larger. If the drawing is made larger than this, it will be more difficult to gage the proper thickness of lines and size of the lettering. If it is smaller, the inevitable imperfections in drafting will be greatly magnified when the slide is shown on the screen. Another advantage to be found in using a drawing three to four times the size of the slide is that it fits a standard letter-size sheet of paper. The drawing sizes in the table, which are between three and four times the size of the slide, all fit the standard letter-size paper. All numbers, captions and clear space for a border should be included within these dimensions.

Suggested Sizes of Drawings for Lantern Slide Openings

Lantern slide opening		*Drawing*	
Width, inches	*Height, inches*	*Width, inches*	*Height, inches*
$2\frac{3}{4}$	$2\frac{1}{4}$	$9\frac{3}{4}$	8
3	$2\frac{3}{4}$	$8\frac{3}{4}$	8
3	$1\frac{3}{4}$	$10\frac{1}{2}$	$6\frac{1}{8}$
$2\frac{3}{4}$	$2\frac{7}{8}$	8	$8\frac{3}{8}$
$2\frac{1}{4}$	$2\frac{3}{4}$	8	$9\frac{3}{4}$

Selecting Scales for Graphs. When the drawing for a slide is to consist of a graph containing one or more curves, the scale for the ordinate and abscissa should be carefully selected to make the size of the significant data as large as possible. It would be good practice to plot the data first as a rough draft on any graph paper available. If the first plotting does not produce a satisfactory graph, a larger or smaller scale may be tried for one or both of the coordinates to improve the appearance, increase the legibility, and produce proportions that will fit the slide opening. It almost invariably helps at this stage to consult the draftsman who is to make the finished drawing. When the graph seems to be suitable for the final drawing, it would be well to ask a few questions about the appearance of the sketch. For instance, will the data fill the available space effectively? Will there be ample space for proper line thickness and lettering? Will the slide be too crowded for instant comprehension by an audience whose attention may be diverted by normal auditorium noises?

In "Aids to Technical Writing," Jordan and Edwards (*1*) state: "It is recommended that a single slide contain not more than 20 words, including the title, and present only one idea." They also make the

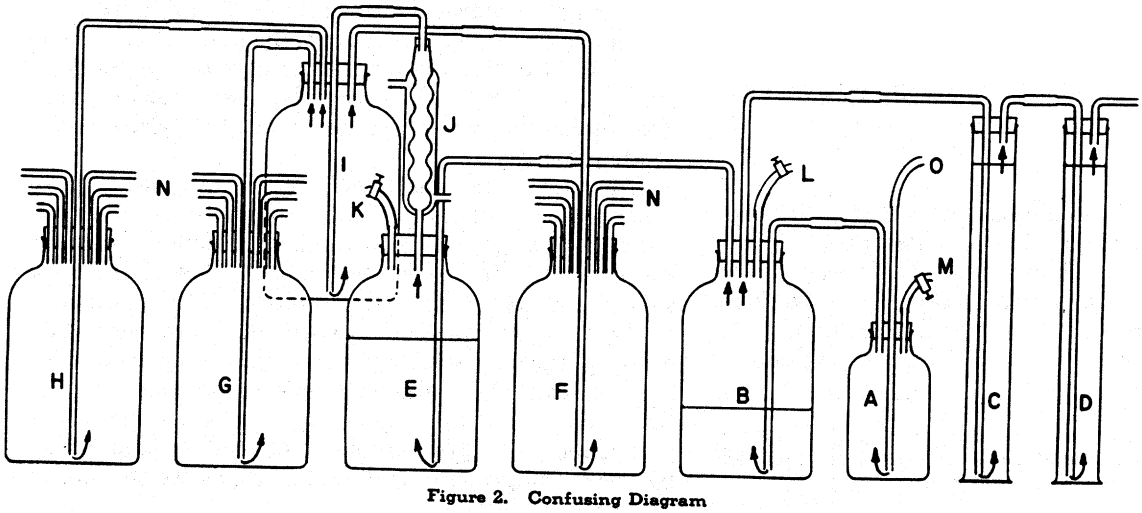

Figure 2. Confusing Diagram

following statement about this type of chart: "If curves presented on charts are not of the same slope and family, it is recommended that, for clarity, not more than three curves be shown on a single slide."

Figure 3 demonstrates the effects of overcrowding. The different angles of slope and the crossing of the curves cause confusion. Figure 4 shows the maximum number of curves that should be drawn on one chart, even though they all be similar.

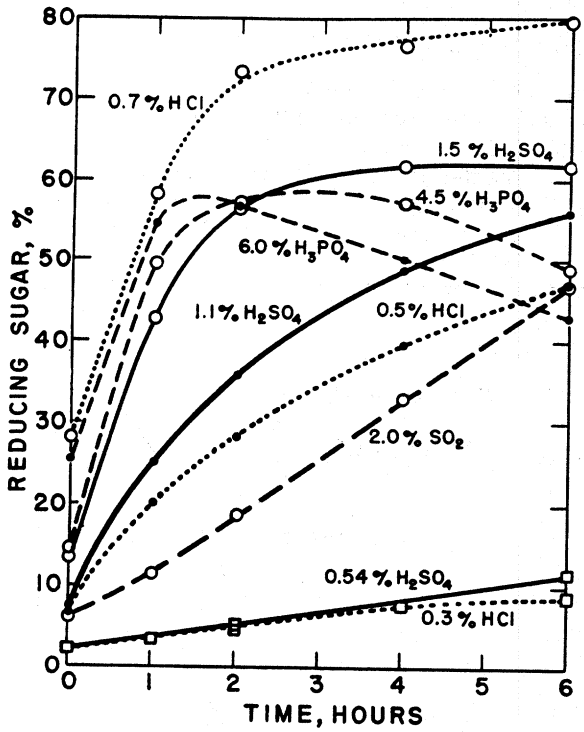

Figure 3. Overcrowded Chart

In regard to the use of tabular data for slides, Jordan and Edwards state: "The use of tables should be avoided wherever possible in oral presentation of scientific data. . . . Detailed tables are impossible to comprehend when flashed on the screen for a short period of time. Furthermore, it is generally found that only a few of the values presented in the tables are actually discussed by the speaker, and little, if any, reference is made to the remaining material." If the author is inclined to use several tables for slides, he should suspect that he has not given enough thought to the audience's reception of his material. He may be trying to give too many data without proper predigestion and selection. If the information can be converted to a graphic illustration, the audience will be able to understand it more quickly and more thoroughly. Tables should be used only if there is no way to illustrate the material by means of a graph or chart. If tables are necessary, no more than 16 items should be included, each word or three-digit number being counted as an item.

Lines for Lettering. Another difficulty often encountered by the technical author—selecting the size of the lettering and thickness of lines—can easily be overcome by planning slide drawings for the sheet sizes recommended in the table. Jordan and Edwards (*1*) show that if the drawing is made approximately three times the size of a proposed slide, the minimum size of the lettering should be that produced by No. 140 lettering guide (Wrico or Leroy) and the minimum line thickness on the drawing should be 0.008 inch (or 0.2 mm.) for background grid, guide, and dimension lines. When an open-background chart is used, the scale-division marks along the border should be approximately twice this thickness. Border lines and letter strokes should be heavier still, and the curves, which are the most important feature of the chart, should be thickest of all (not less than 0.03 inch or 0.75 mm.). Uniformity of thickness of the lines throughout their length is important in work that is to be reproduced photographically; thin spots may fail altogether.

Making the Finished Drawing. If the author is making his own finished drawings, he would do well to observe the precautions listed below. He may also find them useful when checking the work of others.

(*a*) Restrict the number of scale division marks or background grid lines to the few needed for approximate readings only. Interested persons will no doubt request copies of the numerical data.

(*b*) Grid rulings should not run through lettering or data symbols, but may cross curves without interruption.

(*c*) Use simple, easy-to-reproduce data points. The simplest is an open circle having an outside diameter three to four times the thickness of the curve. Its line thickness should be one-third to one-half the thickness of the curve. Use, in the following order, the solid round dot (two and one-half times the curve thickness), the open square, and the open triangle. The square and triangle should fit in a circle five to six times the thickness of the curve, and their lines should have the same thickness as the open circle.

(*d*) When curves represent experimental results, it is good practice to include the points on the drawing.

(*e*) When data points cause crowding or confusion, omit some of them. The important feature of the drawing from the reader's point of view is the curve, not the points.

(*f*) In general, use solid lines for curves. However, variations in the type of line used for curves on the same chart give more positive differentiation than do varied data points. If lines are varied, use, in the following order, the solid line, then lines consisting of long dashes, short dashes, dots, and alternating dots and dashes.

(*g*) Maintain uniformity of symbols and lines throughout the series of drawings.

(*h*) Identify all curves, parts of apparatus, processes, and materials by adjacent horizontal labels, placed so that there can be no mistake about the label that applies to the item. If necessary, use arrows to tie the label to the item. Labels should be brief, not more than two long words or three short ones.

(*i*) Mark coordinates at the left and along the bottom. The American Standards Association (*2*) recommends that the dependent variable be placed vertically along the ordinate, and the independent data across the abscissa, from left to right. The captions for these numerical values should be given in plain vertical letters and should state what is measured or represented, followed by the unit of measurement (for example: TIME, HOURS). A simple system of numbering, consisting of multiples of 5 or 10, should be used.

(*j*) On drawings of apparatus or equipment, include dimensions or other means of establishing the scale.

(*k*) In lettering the drawing, leave a space between the letters at least twice the thickness of the letter stroke. Between words and between lines use a space equal to or greater than the height of the letters. It is the white, open space around the letters or symbols that makes them legible.

Some of these suggestions were taken from the American Standards Association (*2*); others are the result of personal experience. The list could be amplified with many more "do's" and "don't's," but the items omitted will be taken care of by good drafting practice and common sense. It should be emphasized that the author is always responsible for accuracy regardless of who prepares the drawing.

Typewriter Slides. A typewriter may be used for lettering drawings for slides when other means are unavailable, if the size of the drawing is proportioned to fit the smaller lettering. "Radio-Mats" can also be used. These devices, made of cardboard and cellophane, produce legible slides when used for typewritten material. The space available for typing limits the words and numbers that can be included. Typed lettering on "Radio-Mats" will usually project legibly, but graphs or other drawings are beyond their limitations. It is better to draw directly on the window with India ink, although this cannot be expected to adhere very long.

When prepared devices are not available and slides are required urgently, it is also possible to use cellophane or other clear sheeting in the same way that "Radio-Mats" are used. Typing can be made to adhere if carbon paper is placed in the typewriter so that both sides of the slide will receive the impression. J. L. Wilson (*3*) also suggests cardboard stiffening masks for this type of work.

When the minimum sizes of lettering recommended by Jordan and Edwards (*1*) are used, the maximum drawing size should be 2.1 times the slide opening for pica type and 1.9 times for elite type (the usual large and small typewriter types). These measurements will give rectangles within which to work, including all drawings, typing, and borders.

When the lettering is done by typewriter, sharp results can be obtained by using a new ribbon and a good grade of glossy, white paper. Do not try to erase mistakes; it cannot be done easily and is rarely successful. Alterations should be made by typing the correction on a separate piece of paper and cementing it in place with rubber cement.

Checking the Slide. A simple way to determine whether a slide will project well is to inspect it from a distance of 20 inches. If all parts can be distinguished easily when it is held toward a well-lighted, light-colored surface, it will project satisfactorily. Similarly, if a drawing three times the size of the finished slide can be read easily at three times 20 inches, a well made slide from this drawing will also be satisfactory.

DRAWINGS FOR PUBLICATION

When an author is planning to publish an illustrated manuscript in a technical publication, he should first examine several copies of the periodical. He should notice the details of the illustrations, keeping in mind that the drawings have been photographically reduced to conserve space and make the cut fit the

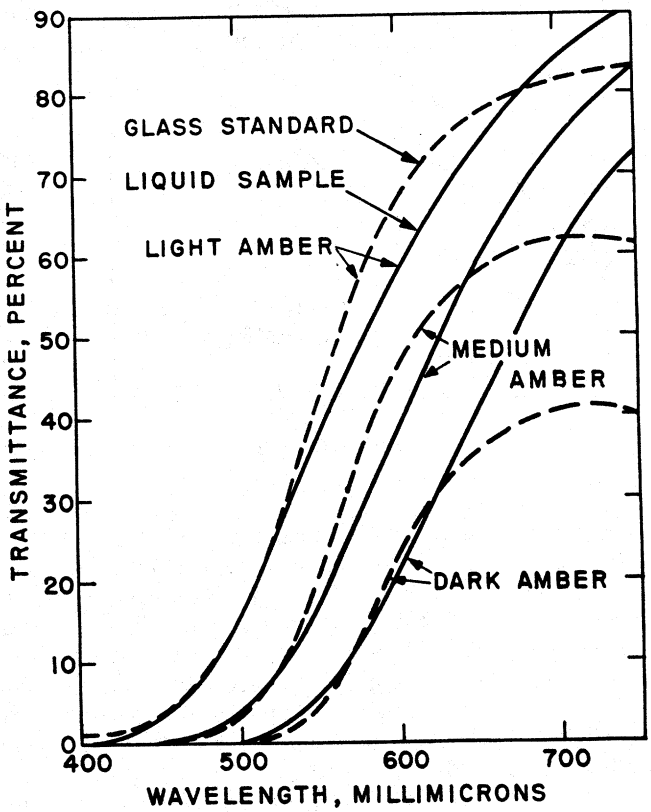

Figure 4. Maximum Material for a Chart

width of the column. In technical periodicals the column may be from $2^1/_8$ to 6 inches wide. The difference between the width of the proposed drawing and the column width will determine the amount of reduction the drawing will require. Unlike drawings for slides, drawings for publication may have an elastic vertical dimension. The vertical size of illustrations may be expanded or compressed to emphasize some aspect of the data or reduce its importance with respect to horizontal components. Careful consideration and consultation at this time with the draftsman or other authors often result in changes that improve

the visual impact of the data or make rapid comprehension easier for the reader.

Another difference between drawings for publication and those for slides is the amount of reduction required for good results. Drawings for slides should allow enough reduction to reduce imperfections so that they will not be noticeable when greatly enlarged on a screen. Drawings for publication, however, need only moderate reduction. If it were not for the difficulty of drawing thin lines and microscopic lettering, these drawings could be prepared for exact-size reproduction.

To avoid some of the difficulties in drafting, it is recommended that drawings for publication be planned to allow a reduction in width of one-third to two-thirds. This reduction requires that the width of the drawing

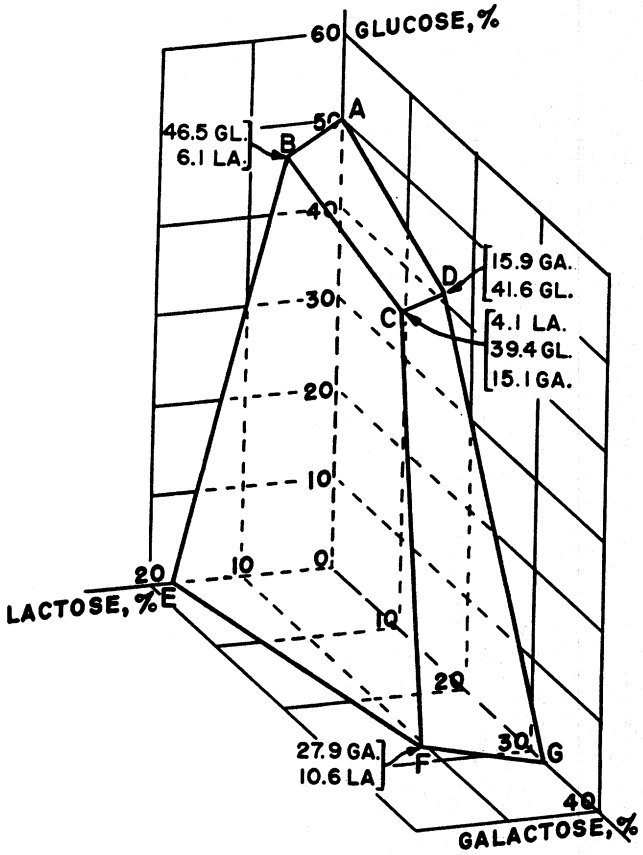

Figure 5. Dimetric Illustration of Three-dimension Data

be one and one-half to three times the width of the finished cut. The height of the drawing should then be planned to show the data to advantage but not waste space. It would be well at this time to consider the proportions of rectangular drawings. To avoid awkward rectangles, Hambidge (*4*) suggested the use of one of the following ratios: 1.414 to 1.0, 1.732 to 1.0, 1.0 to 1.0, 2.0 to 1.0, and 2.236 to 1.0. These ratios are based on measurements of many buildings and art objects.

Lines and lettering should next receive attention. Since in a finished cut lines thinner than 0.006 inch may fail to reproduce properly in spots, it would appear advisable to use this as a minimum and determine the thickness of lines on the drawing by means of the ratio of width of drawing to width of cut. Other lines should be proportionally thicker as described under drawings for slides.

To be legible, lettering on a finished cut should never be less than $^1/_{16}$ inch high. The minimum size of lettering on the drawing can be determined by using the ratio indicated above. Lettering should be plain and neatly spaced. In general, to provide interest and contrast with the grey body of text, the lines and lettering should be larger and heavier than the minimum recommended.

Sheet Size. It cannot be too strongly emphasized that drawings both for slides and publication should be made on letter-size sheets. Drawings smaller than the standard 8 by $10^1/_2$ inches or $8^1/_2$ by 11 inches may be easily lost, because envelopes and filing cabinets are made for this size sheet. Drawings larger than letter size cause great inconvenience, because they require folding or rolling to be mailed or stored. If larger drawings are necessary, they should be in multiples of this size.

READER INTEREST

At some point in the process of illustrating his manuscript, the author might well think about the effect his drawings will have on the reader or audience. A report may be remembered for either of two reasons—because of interest in the subject or because it is presented in an unusual way. Compare the average scientific report with articles in technical periodicals intended for the general public. Much of the effectiveness of the latter is a result of dramatic illustrations.

Has anyone tried publishing a technical report that contains nothing but illustrations, their captions, the summary, and the bibliography? Possibly a time may come when words will be accessory to illustrations in the technical field, as in today's pictorial newsmagazines. Many readers will recall attending excellent seminar lectures that consisted entirely of slides with a brief discourse about each. Usually, however, this proportion of words to illustrations is not retained when the report is published.

For an exposition of a way to reduce statistics to a striking image-language story on a chart, the reader is referred to "How to Use Pictorial Statistics," by Rudolf Modley (*5*). Basic rules are given for the production of striking charts. The author emphasizes that considerable study is needed to present statistics with the strongest graphic effect, but states that it is well worth the effort.

The type of drawing can of itself stimulate the reader's interest. The drawings easiest to comprehend are the isometric, dimetric, and perspective projections with parts "exploded" or cut away to show the hidden details. Plastic drawing guides and special, perspective sketch books are now available for making these drawings, including the ellipses of many shapes and

sizes needed for this work. These systems can be extremely effective when used for flow diagrams and equipment illustrations. Figure 5 shows an unusual dimetric chart that illustrates data with three variables.

Color can be used on lantern slides to make them attractive and to help distinguish the parts. An easy method is to have the chart reproduced as a negative of the correct size for a slide, and then color the separate curves or bars with photographer's transparent water colors. This kind of work will probably be confined to slides, because few journals are equipped for profuse color printing.

Eye-catching devices such as these can make a scientific report stand out from the average hard-to-read treatise. Many authors will no doubt conceive still other methods of enriching their reports.

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